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Ultrasound measured collapsibility of inferior vena cava comparison with central venous pressure in critically ill patients

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ABSTRACT

Objective: In critically ill intensive care unit patients, the link between central venous pressure (CVP) readings and ultrasound measurements of the inferior vena cava diameter and collapsibility index was investigated. *Methods*: This prospective, observational study included 90 patients aged 18 to 65 years of either sex, ASA II-III, admitted to the ICU (intensive care unit) of ALzahraa teaching hospitals with a working central venous catheter implanted for any clinical indication. Hemodynamic measurements were taken on a regular basis, such as non-invasive mean arterial blood pressure. When the CVP (central venous pressure) measurements were performed, the patient was in a supine position. The maximum and minimum collapsibility indexes are then determined using ultrasonography to measure the diameter of the IVC (inferior vena cava). The association between CVP and the IVC collapsibility index was assessed using Spearman's correlation coefficients. *Results*: In our study, there was a significant correlation between CVP and the two studied ultrasound parameters, IVC CI and IVCdmax. According to the receiver operating characteristic curve (ROC), the inferior vena cava collapsibility index (IVC CI) had the best performance of the two ultrasonography measures in predicting CVP 10 cm H2O, according to the receiver operating characteristic curve (ROC). *Conclusions:* The collapsibility index of IVC and CVP were discovered to have a strong negative connection in this study. This finding suggests that the IVC collapsibility index could be used instead of CVP to determine the intravascular volume status.

Keywords: ultrasound, inferior vena cava, pressure measurement

1. INTRODUCTION

The ability to assess and monitor intravascular volume status is crucial in the care of critically ill patients. Volume status is now determined by physical

examination, vital sign evaluation, biochemical marker evaluation, tissue perfusion, and central venous pressure (CVP), as well as sonographic measurement of inferior vena cava (IVC) diameter (Wilson et al., 2003). Physical examination is unreliable for detecting intravascular volume status, despite being one of the simplest and fastest techniques (Brennan et al., 2007). Blood pressure, on the other hand, may remain stable until 30% of total body water has been depleted, which is enough to cause organ dysfunction (Manning, 2004). The blood pressure in the thoracic vena cava near the right atrium is known as central venous pressure (CVP) (Klabunde, 2011), by describing how a function that describes the return of blood to the heart (venous return function) and a process that describes the output from the heart determine cardiac output (cardiac function) (Magder, 2012). CVP is the equilibrium value of these two functions in the intact circulation. A change in CVP should be viewed as a shift in the cardiac and return functions, rather than just a change in preload (Bishop et al., 1964).

CVP increases and cardiac output decreases, indicating a primary decline in cardiac function that is best addressed by enhancing cardiac function. A decrease in CVP and an increase in cardiac output indicate that heart function has improved quickly. When the link between IVC diameter and intravascular volume is explored, CVP is regarded the gold standard (Nagdev et al., 2010). The gold standard for measuring CVP and right atrial pressure is central venous catheterization (RAP). The risks of infection, catheter-induced thrombosis, and arrhythmias prevent this invasive procedure from being used on a large scale or on a regular basis (Kido et al., 1988). As a result, non-invasive CVP estimation techniques are critical in enabling more widespread CVP evaluation in clinical practice (Beigel et al., 2013).

The objective of the current work was to examine noninvasively whether real-time ultrasonographic measurements of the IVC correlate with a patient's known CVP and predict the correlation between the IVC diameter and the CVP.

2. PATIENTS AND METHODS

Study design and setting

This cross-sectional study was performed in the intensive care unit of a tertiary center in Al-Zahraa teaching hospital in Wasit and included ninety ICU patients aged 18–65. The study was carried out between January 2020 till March 2020.

Inclusion criteria

- Age greater than 18 years.
- Hemodynamic stability (i.e., on mechanical ventilation).
- Able to lie supine.
- Normal body mass index (BMI).
- Mechanically ventilated using Positive End-Expiratory Pressure (PEEP) with already inserted a central venous catheter (CVC) subclavian or the internal jugular vein by proper indication for CVP measurement.

Exclusion criteria

- Bilateral central venous catheters or femoral catheters.
- A history of radiotherapy to the neck or chest
- Previous or active upper extremity deep venous thrombosis
- Within 2 hours of the study, administer vasoactive medications (vasoconstrictors or diuretics) to attain hemodynamic stability.
- Clinically significant tricuspid or mitral regurgitation
- A recent incision in the chest or abdomen (post laparotomy)
- Increasing abdominal pressure, intrathoracic pressure

Study variables

The CVP is measured manually using a manometer at midaxillary level with the patient lying supine. To keep the test as simple as possible, and because the relationship between IVC diameter and respiratory cycle in intubated patients is controversial, the ventilated patient's maximum and minimum IVC diameter was measured without regard to phases of the respiratory cycle. Maximum and minimum IVC diameter measurements were obtained by M mode of ultrasound view under subxiphoid approach, 1to 2 cm below the level of the hepatic veins. An IVC collapsibility index (IVC-CI) calculated with the following formula:

$$(IVC - CI) = \frac{(IVC_{max} - IVC_{min})}{IVC_{max}}$$

IVC-CI measurements were grouped by range (<20%, 20% to 60%, and >60%) and analyzed for the presence of substantial differences in CVP between the three IVC-CI groupings.
Patients have CVP < 7 mmHg of CVP were considered to have hypovolemia (Stawicki et al., 2009).

Statistical analysis

For both qualitative variables, descriptive statistics were produced. To compare distinct IVC-CI groups and systolic, diastolic, and MAP, a one-way analysis of variance (ANOVA) was utilized. The significance of CVP and IVC CI was determined using the Pearson correlation coefficient. The IVC-CI value corresponding to CVP less than seven mmHg was determined using the Receiver Operator Characteristic (ROC) curve. Throughout the study, a p-value of less than 0.05 was considered significant.

3. RESULTS

This study included 90 patients who were admitted with CVP monitoring. Their mean age was 40.7±12.74 years; their mean BMI was 27.5 ± 5.1 kg/m^2; other variables , including systolic, diastolic, and MAP, were shown in Table (1).

Table 1 basic characteristic of the study population

Variables	Mean	SD
Age (y), mean ± SD	40.7	12.74
BMI (kg/m^2), mean ± SD	27.5	5.1
Systolic blood pressure (mmHg), mean ± SD	123.5	32.6
Diastolic blood pressure (mmHg), mean ± SD	77.2	15.4
Mean arterial pressure (mmHg), mean ± SD	96.3	21.2
PEEP	5.7	1.3

Patients with an IVC-CI index lower than 20 had only one patient with CVP less than seven mmHg, while those with an IVC-CI index of 20-60 had 13 patients out of 53 with CVP <7 mmHg, and most of the patients with IVC-CI index >60 had low CVP. There were significant negative correlations between CVP and IVC-CI index and between age and IVC-CI index, which meant that as the CVP and age increased, the index decreased, but there were no significant correlation with other variables, as shown in Table (2).

Table 2 correlation of some variables with IVC-CI index

Variables	Correlation coefficient (r)	P-value
CVP	-0.632	<0.001
Age	-0.231	0.029
Height	-0.081	0.450
Weight	0.102	0.338
BMI	0.120	0.260
Systolic BP	-0.159	0.134
Diastolic BP	-0.092	0.389
MAP	-0.140	0.188

Table 3 shows that the CVP was 6.3 ± 0.865 mmHg in patients with >60 CI, increasing to 8.6 ± 2.5 mmHg in 20-60 CI, and reaching 12 ± 3.71 mmHg in <20 CI, also the percentage of lower-than-seven CVP decreased with decreasing CI ratio. There was a statistically significant ROC model for identifying the optimal cut-off value of CI for diagnosing CVP less than seven mmHg in our study sample, and if a cut-off value of >47 CI, it would have 80.98% sensitivity and 76.81% specificity for CVP lower than seven mmHg, with a good area under the curve (AUC, 0.745), as shown in Figure (1).

Table 3 correlation and CVP values according to IVC-CI index

Variables	Values
IVC-CI >60 (Number= 12)	
CVP (mmHg), mean ± SD	6.3 ± 0.865

% with CVP <7 mmHg	58.3%
Median CVP	6.5
IVC-CI 20-60 (Number= 53)	
CVP (mmHg), mean ± SD	8.6 ± 2.5
% with CVP <7 mmHg	24.5%
Median CVP	8
IVC-CI <20 (Number= 25)	
CVP (mmHg), mean ± SD	12.0 ± 3.71
% with CVP <7 mmHg	4%
Median CVP	12

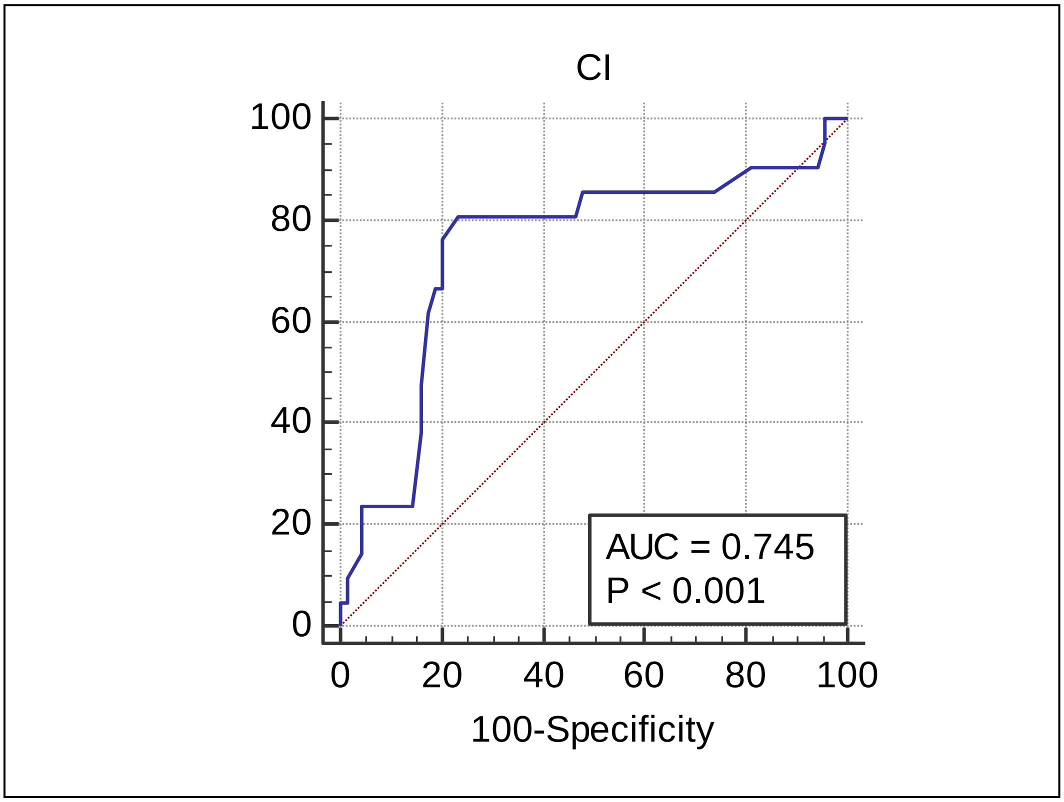

Figure 1 ROC analysis for IVC-CI for CVP less than seven mmHg

4. DISCUSSION

CVP is used as an invasive method to estimate the preload and blood pressure in the right cardiac atrium in intensive care units. Still, it's not that accurate, as once was believed, because it is affected by intravascular volume, vascular compliance, fluid responsiveness, in addition to being invasive, technically demanding, and operator dependent (Monnet et al., 2016), that motivated us to investigate the IVC collapsibility as an alternative method. In the current study, there were significant weak-negative correlations between age and IVC-CI index (r: -0.231, P: 0.029), which meant that as the age increased, the index decreased. This was comparable to the results of Masugata et al., (2010) in Japan, who studied 200 patients with cardiovascular disease risk factors and reported the same finding with a correlation of -0.221 for decreasing maximum IVC diameter with increasing age. But another study was done by Patil et al., (2016) in India, who studied a large sample of 4126 healthy individuals and reported that IVC-CI was not correlated with age. This can be explained by accompanying atherosclerosis of blood vessels in older patients with a risk factor for this condition. With the hardening of the vessel walls, the compliance will decrease, and the IVC wall will not respond to intravascular volume changes like the younger population with healthier blood vessels.

In the current study, from patients with IVC-CI index lower than 20, had only one had CVP less than seven mmHg, while those with IVC-CI index of 20-60 had 13 patients out of 53 with CVP <7 mmHg, and most of the patients with IVC-CI index >60 had low CVP. These results were comparable to Stawicki et al., (2009) in the USA, who investigated 83 patients admitted to ICU. They

reported that less than 5% of patients with low CVP had IVC-CI more than 20%, 35% of them had an index from 20-60%, and more than 60% had CI more than 60%. In another study done by Thanakitcharu et al., (2013) in Thailand who studied 70 critically ill patients, and reported that in state of hypovolemia, the mean CI was 45.69 ± 16.15 %, while in state of euvolemia, the CI was 31.23 + 16.77%, and state of hypervolemia the index was 17.82 + 12.36 %.

In the current study, there were significant moderate-negative correlations between CVP and IVC-CI (r: -0.632, P:<0.001), which meant that as the CVP increased, the index decreased. Multiple studies reported similar results but with different correlation levels. The use of IVC-CI appears tempting because it's non-invasive, lower coast as the same ultrasound device can be used for a diverse and indefinite number of patients, and can be done at the bedside, but it's operator dependent, without clear guideline for the cut-off values that indicate hyper/hypovolemia, and at time being cannot be used alone as an indicator for intravascular volume status. Despitethese negative aspects, such examination has a promising future in the field of intensive care.

In the current study, there were no statistically significant differences between systolic blood pressure between different CI index classes, and the same applied to diastolic and MAP; this was in agreement to results of (Thanakitcharu et al., 2013) in Thailand, who reported that all the mentioned blood pressure parameters did not have statistically significant differences between hypovolemic, euvolemic, or hypervolemic patients. The same findings were also reported by (Nagdev et al., 2010). This can be explained by the fact that changes in bloop pressure take more time than directly monitoring the CVP, and blood pressure, pulse pressure measurements, in addition to CVP measuring, are used to monitor volume status during fluid replacement. Still, the decision for fluid administration should be based on the entire clinical presentation, laboratory values, and the modalities mentioned above.

5. CONCLUSION

Measurements of IVC-CI by sonography can provide a valuable guide to non-invasive volume status assessment in ICU patients, and IVC-CI appears to correlate well with CVP. It is possible to make a cut-off value that identifies hypovolemia after controlling for confounding variables.

Author contribution

Maytham Murtadha Kadhim: Conception and design of the work, the acquisition, analysis, interpretation of data for the work, and Drafting the work.

Abdul Sattar Hadi Ibrahim: Conception and design of the work, interpretation of data for the work, and revising it critically for important intellectual content

Muthana Abdul Kadhim Saad: Conception and design of the work, and Drafting the work, and finally revising it critically for important intellectual content

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Conflict of Interest

The authors declare that there are no conflicts of interests

Informed consent

Written informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this manuscript.

Ethical approval for human

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards (Code: 2020/0119).

Data and materials availability

All data associated with this study are present in the paper.

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